



TECHNICAL PAPER

STANDARDIZED UXO DEMONSTRATION SITES

GEOPHEX, LTD. GEM-3 EMI/PUSHCART AND TOWED

OPEN FIELD SCORING RECORD NO. 129



GEM-3 EMI pushcart system was demonstrated by Geophex, Ltd. of North Carolina.

The GEM-3 EMI/Pushcart and Towed detection system was demonstrated by Geophex, Ltd. at the Aberdeen Proving Ground Open Field Grid Area. This technical paper contains the results of that demonstration. This is a reference document only and does not serve as an endorsement of the demonstrator's product by the US Army or the Standardized UXO Technology Sites Program.



Technologies under development for the detection and discrimination of unexploded ordnance (UXO) require testing so that their performance can be characterized. To that end, standardized test sites have been developed at Aberdeen Proving Ground, Maryland, and Yuma Proving Ground, Arizona. These test sites provide a diversity of geology, climate, terrain, and weather as well as diversity in ordnance and clutter. Testing at these sites is independently administered and analyzed by the government for the purposes of characterizing technologies, tracking performance with system development, comparing performance of different systems, and comparing performance in different environments.

The Standardized UXO Technology Demonstration Site Program is a multi-agency program spearheaded by the US Army Environmental Center. The US Army Aberdeen Test Center and the US Army Corps of Engineers Engineering Research and Development Center provide programmatic support. The program is being funded and supported by the Environmental Security Technology Certification Program, the Strategic Environmental Research and Development Program, and the Army Environmental Quality Technology Program.

DEMONSTRATOR'S SYSTEM AND DATA PROCESSING DESCRIPTION

GEM-3 electromagnetic induction (EMI) sensors are multi-frequency (up to 10 frequencies logarithmically spaced in the 30 Hz to 47930 Hz range) sensors consisting of three concentric coils and digital electronics. The outer coil is the primary transmitter, the inner coil the receiver, and the annular coil is a secondary (bucking) transmitter that creates a primary field cavity around the transmitter. The electronics includes a digitally controlled switching H-bridge transmitter current-source, a 24-bit analog to digital (A/D), and a digital signal processor with random access memory and flash memory and serial data ports (RS-232). A user interface consists of a palm pack computer with Geophex software; commercial digital Global Positioning System (DGPS) is fully integrated.

The system is a continuous wave frequency domain system in which data are recorded while the transmitter is on; the transmitter waveform consists of a continuous mix of superposed sine waves at the specified frequencies. The measured raw time-series data are voltages (pre-amplified) measured by the receiver coil and by a small reference coil located in the transmitter primary/bucking coil annular space (proportional to primary field and phase referenced to primary field), and sampled by the A/D. Data are pre-processed in units of 30-Hz intervals (base periods) and averaged over a selectable number of base periods, typically two for cart-survey operation (net output rate of 15 Hz).

The cart-mounted configuration, with a 96-cm diameter coil disk mounted on either a manually pushed composite material wheeled cart or an all-terrain vehicle (ATV) towed wooden wheeled cart, is used in environments where a large sensor on a wheeled cart is practical and wide-area coverage required, such as flat, open terrain. The ATV towed system is augmented with a navigation system that provides the driver with steering indicators in order to maintain preplanned survey lines, but it requires greater room for turning than the hand-pushed cart. The actual sensors are identical and can be interchanged. A DGPS system is integrated with the GEM console, and the antenna mounted directly above the sensor provides geo-referenced data, which are recorded in the GEM console flash memory and/or the system (laptop PC) computer. Data are post-processed for target detection/classification.

The front-end data processing is performed in real-time by the system DSP. This processing consists of performing a partial digital fourier transform (DFT) on the receiver and reference time series provided by the A/D at 96 kHz. The DFT frequency samples correspond to the logarithmically spaced transmitted frequencies characterizing the hybrid current waveform. Complex division of the receiver and reference DFT outputs are performed, and system transfer function (calibration) corrections are applied, to generate inphase and quadrature measurements at each frequency. These data are recorded in the console flash memory and/or output to the system computer.

Further processing, performed during post-processing, consists of color-contour map generation using commercial software such as Geosoft®. Target detection utilizes either a composite measurement such as the sum of the quadratures over all frequencies, or a weighted average apparent conductivity over all frequencies. Anomalies identified from the maps may be further scrutinized in profile format. For target discrimination, a spectral matching algorithm compares the measurement with a library of known possible target spectra; this algorithm allows for a linear combination of the intrinsic longitudinal and transverse target response. The quality of the best fit (i.e., rms or mean absolute error) is compared with a threshold for clutter declaration and used as a confidence measure.

PERFORMANCE SUMMARY

Results for the open field test broken out by size, depth, and nonstandard ordnance are presented in the table below. Results by size and depth include both standard and nonstandard ordnance. The results by size show how well the demonstrator did at detecting/discriminating ordnance of a certain caliber range. The results are relative to the number of ordnance items emplaced. Depth is measured from the geometric center of anomalies.

The response stage results are derived from the list of anomalies above the demonstrator-provided noise level. The results for the discrimination stage are derived from the demonstrator's recommended threshold for optimizing UXO field cleanup by minimizing false digs and maximizing ordnance recovery. The lower 90 percent confidence limit on probability of detection and Pfp was calculated assuming that the number of detections and false positives are binomially distributed random variables. All results have been rounded to protect the ground truth. However, lower confidence limits were calculated using actual results.

SUMMARY OF OPEN FIELD RESULTS FOR GEM-3 EMI

Metric	Overall	Standard	Non-Standard	By Size			By Depth, m		
				Small	Medium	Large	< 0.3	0.3 to <1	>= 1
RESPONSE STAGE									
P_d	0.35	0.35	0.30	0.25	0.35	0.40	0.45	0.30	0.05
P_d Low 90% Conf	0.30	0.30	0.26	0.21	0.31	0.33	0.39	0.27	0.03
P_{fp}	0.30	--	--	-	-	-	0.30	0.30	0.30
P_{fp} Low 90% Conf	0.29	--	--	-	-	-	0.28	0.28	0.16
BAR	0.05	--	--	-	-	-	-	-	-
DISCRIMINATION STAGE									
P_d	0.25	0.20	0.25	0.15	0.35	0.20	0.30	0.20	0.05
P_d Low 90% Conf	0.20	0.18	0.19	0.11	0.28	0.13	0.27	0.16	0.01
P_{fp}	0.15	--	--	-	-	-	0.20	0.15	0.15
P_{fp} Low 90% Conf	0.16	--	--	-	-	-	0.16	0.15	0.03
BAR	0.00	--	--	-	-	-	-	-	-

Response Discrimination Stage Threshold: 4.50

Note: The recommended discrimination stage threshold values are provided by the demonstrator.

